

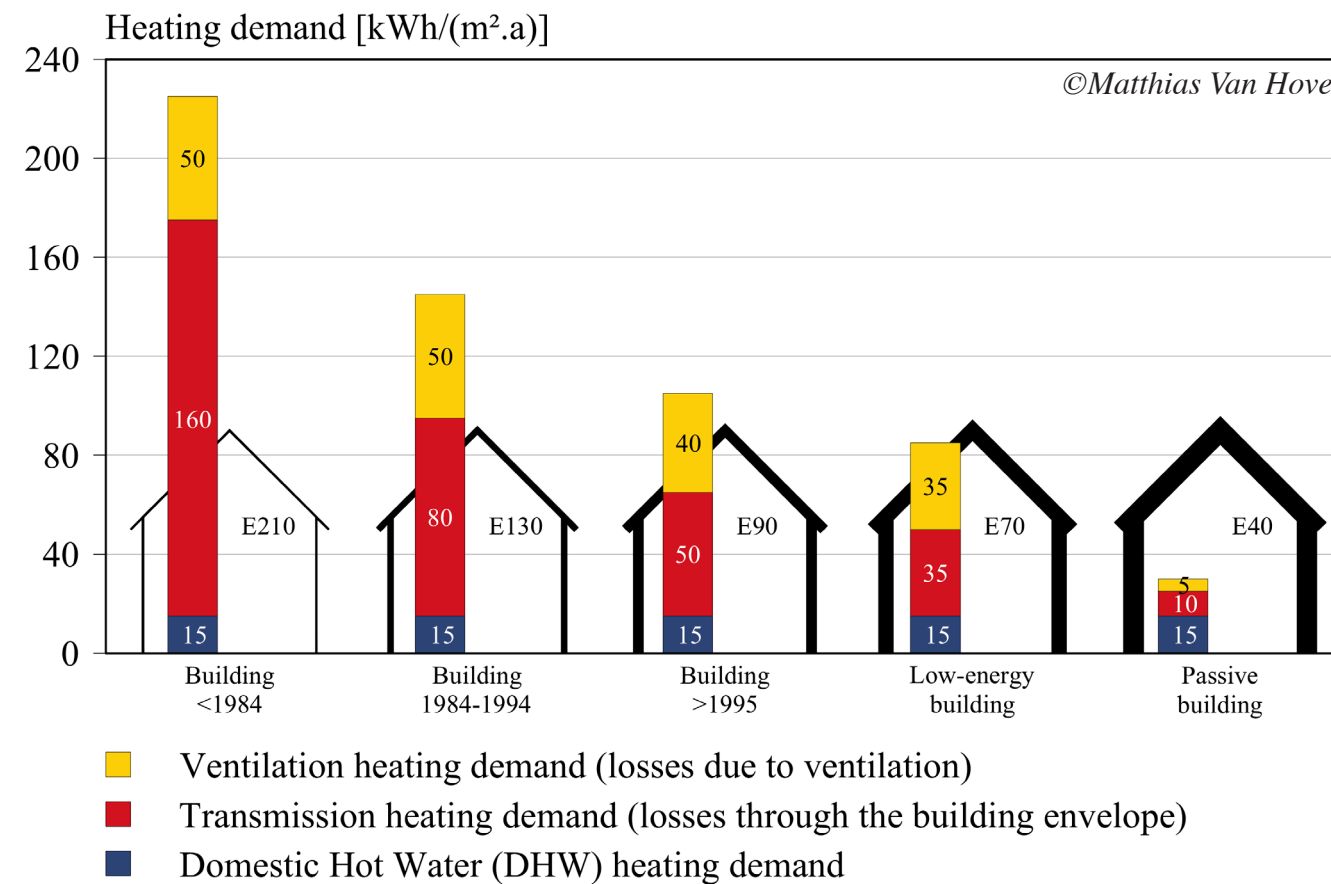
Design and operation of domestic hot water systems: optimisation using building energy simulation

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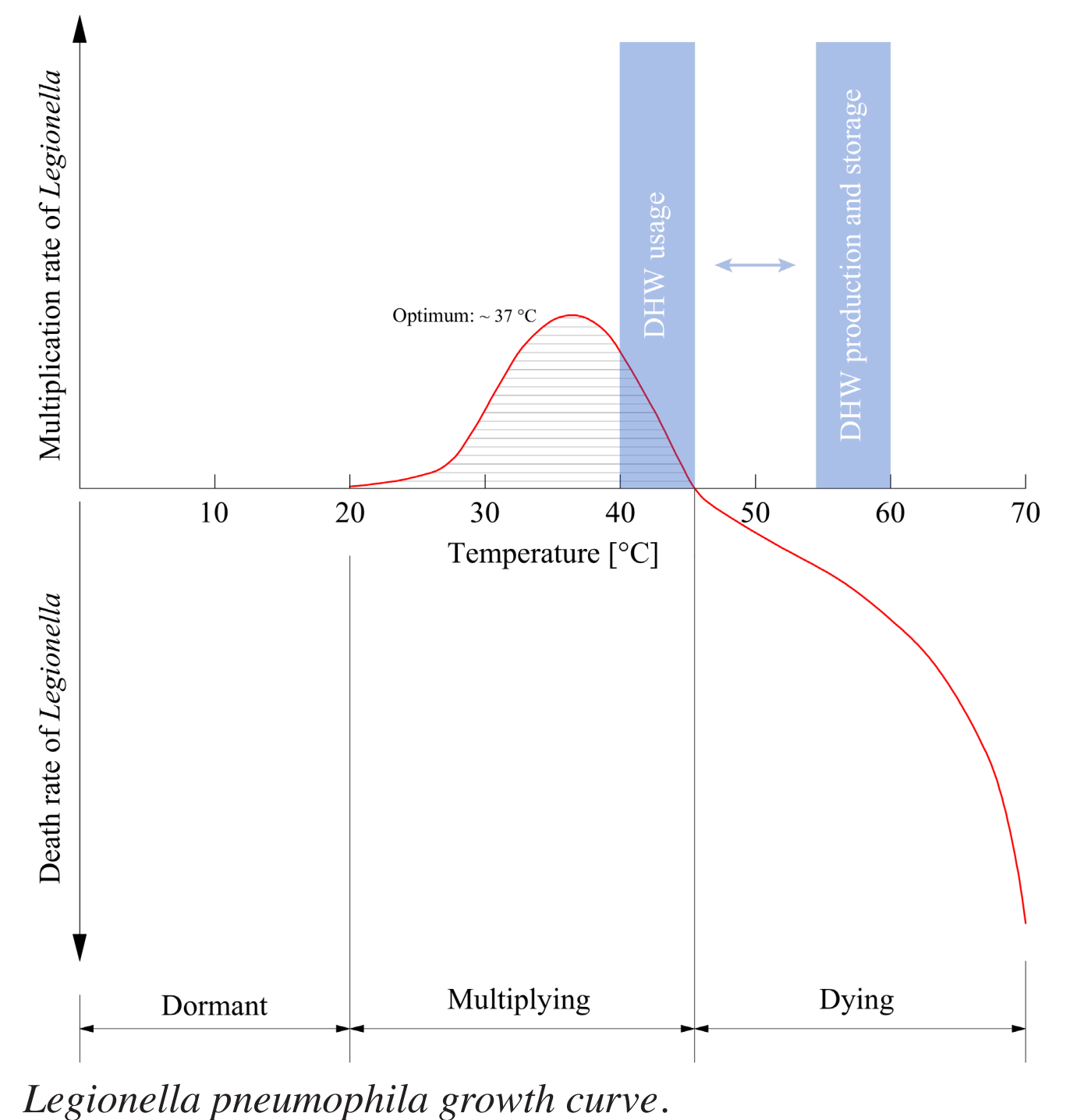
ABSTRACT — Achieving energy savings in buildings is important to restrain global warming and attain the targeted reduction of CO₂-emissions. In well insulated and airtight buildings, Domestic Hot Water (DHW) production accounts for 50% of the total heating demand ►, due to unaltered high production and storage temperatures (which ensure *Legionella*-poor DHW systems, but account for a major disparity between DHW production and storage temperatures and DHW usage temperature). ►

In order to address and study this issue, Dymola simulations models, representing a BBRI test facility, are developed (WP1). With this test facility, a new boiler temperature control scheme is tested both thermodynamically as well as biologically (*Legionella pneumophila* concentrations).

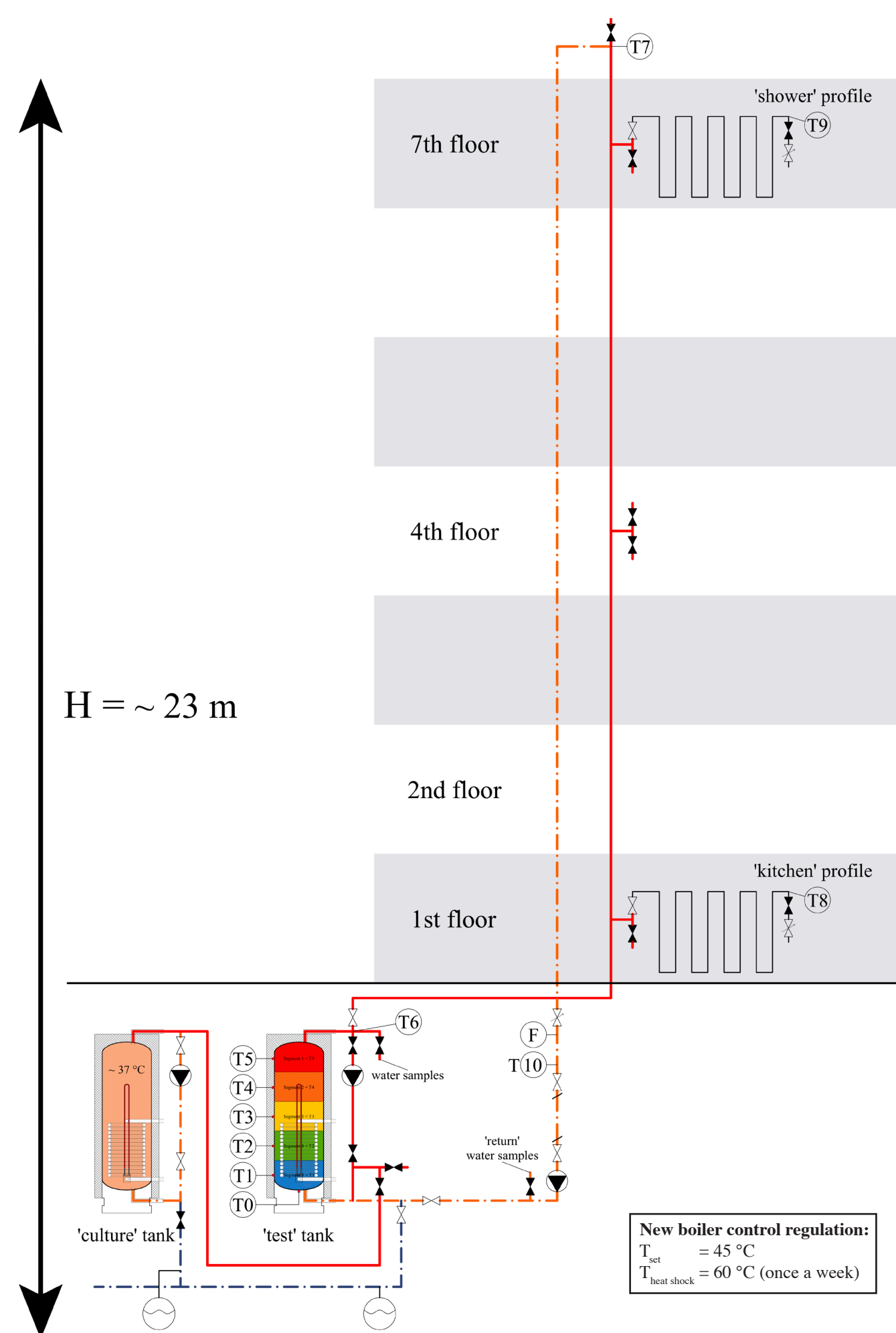
The findings of WP1 are then applied to a case study, in which *Legionella* issues are present, in order to solve the biological problems and to come up with system design and operation optimisations which will lead to significant energy savings.



Comparison of the heating demand for residential buildings of different age and energy efficiency level.



Legionella test facility



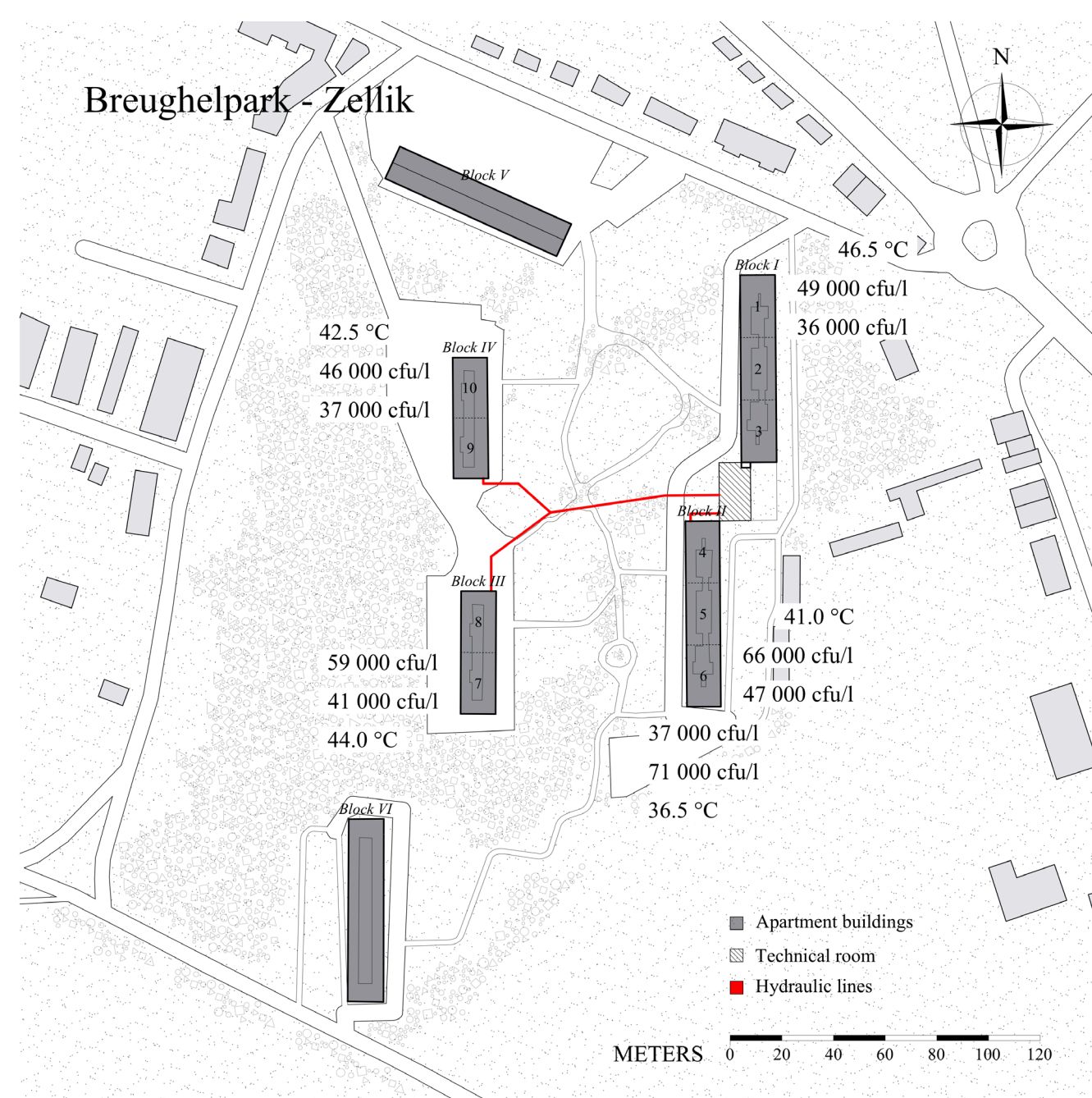
Hydraulic scheme of the Legionella test facility (at BBRI) (©Matthias Van Hove).

For the BBRI test facility, RMSE-values between 0.51 and 2.15 K, MBE-values between -0.010 and 1.199% and CV(RMSE) between 0.158 and 0.734% are achieved for the validation of the thermohydraulic Modelica system simulation model. Furthermore for the *Legionella pneumophila* growth model RMSE-values between 435 and 714 cfu/l, MBE-values between -0.000527 and -0.000561% and CV(RMSE) between 0.00069 and 0.00133% are achieved.

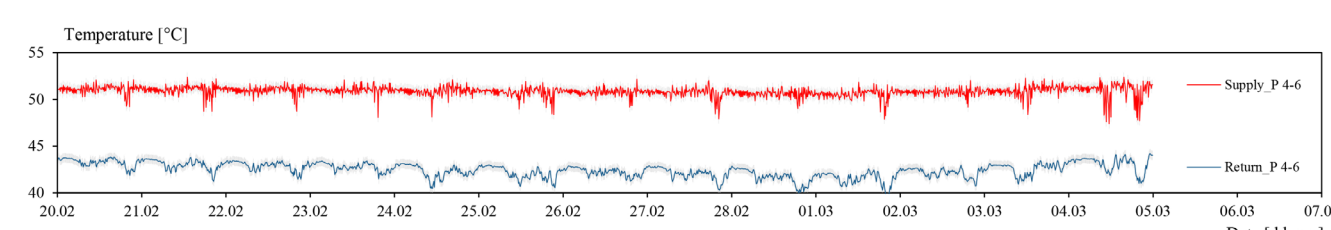
The test facility is considered calibrated thermodynamically (for a normal thermostat regulation at 45 °C with the heat shock every week up to 60 °C) and biologically (for *Legionella pneumophila*).

Breughelpark: Thermodynamic and biologic retrofit of DHW system

The case study project consists of 4 apartment buildings (block I-IV) with 520 apartments (see above) of which both hot and cold water are infected with *Legionella* (e.g., measured DHW temperatures). A system simulation model of these case-study buildings is developed in Dymola, verified with previously executed water temperature, mass flow rate and *Legionella pneumophila* concentration measurement data.

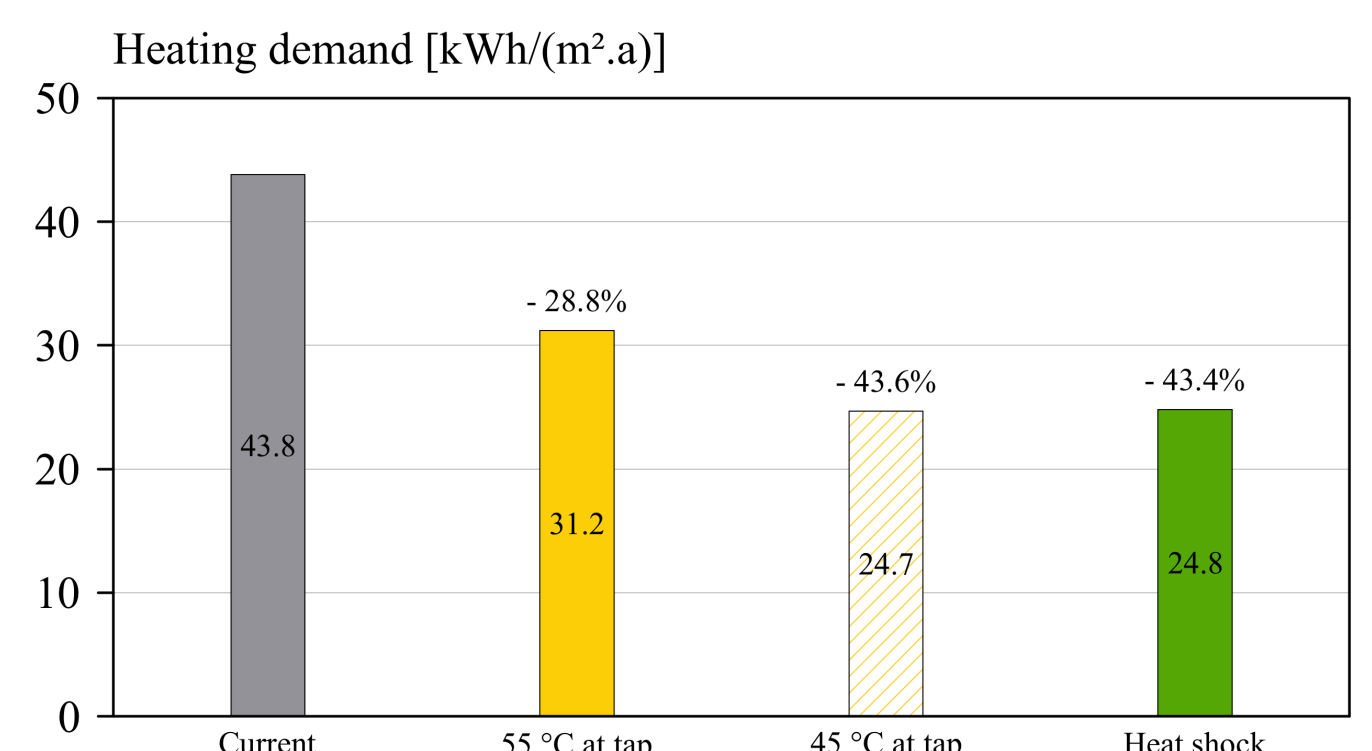


Site plan of the apartment blocks, which are located at Breughelpark. The DHW pipes in between the apartment buildings (I-IV) are illustrated by the red lines and verified with a thermography camera. (©Matthias Van Hove).

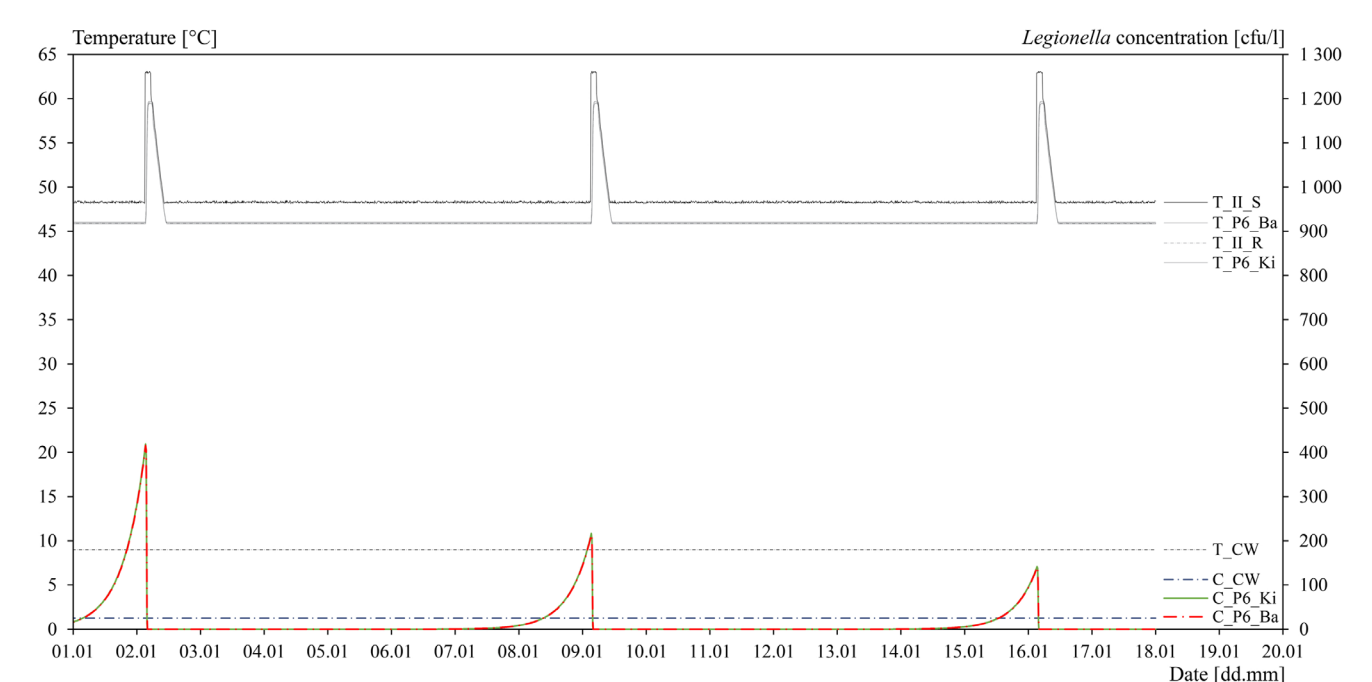


Supply and return water temperature to block II (pavilion 4-6). Return temperatures are below 45 °C so Legionella can occur in the system (see growth curve).

An energy saving potential analysis, followed by biological safety tests (low *Legionella pneumophila* risk), is executed by testing several system design and operation modifications. ►



Energy saving potential analysis for the DHW system of the Breughelpark building site.



Heat shock regulation in the DHW system. *Legionella pneumophila* concentrations are demonstrated in colour on the right ordinate. Corresponding DHW temperatures are demonstrated in black and grey on the left ordinate. Heat shocks once a week prove to be sufficient to keep Legionella concentrations under control (maximum in Belgium = 1000 cfu/l).

Conclusions

- DHW systems can be accurately modelled in Dymola simulation software as well as calibrated and validated both thermodynamically (i.e., water temperature and flow rate) and biologically (i.e., concerning *Legionella pneumophila* growth)
- The new DHW temperature setpoint regulation (with heat shocks) corresponds to 15% energy savings and is biologically safe (i.e., *Legionella* concentration). Together with system design modifications, energy savings for DHW can be as high as 43.4%.